APPARATUS AND METHODS FOR THRUST SENSING VALVES

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FIELD OF THE INVENTION

The present disclosure relates to apparatus and methods for thrust-sensing valves, and more specifically, to valves that automatically retract a drilling device when thrust goes to zero.

BACKGROUND OF THE INVENTION

Typically, the stroke of power feed drilling equipment is adjusted for the maximum material thickness in the area drilled. This results in excessive cycle time drilling holes through the thinner materials in that area. In addition, to accommodate material thicknesses that vary to a greater degree, production frequently has to set-up multiple pieces of power feed drilling equipment that are identical except for stroke adjustment. This situation results in the need for additional power feed drill motors and additional time to set-up and control

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those drill motors. Thus, a need exists to reduce to waste and inefficiency associated with such fixed-stroke drilling apparatus.

SUMMARY OF THE INVENTION

The present invention is directed to apparatus and methods for thrust-sensing valves, and more specifically, to valves that automatically retract a drilling device when thrust goes to zero. Apparatus and methods in accordance with the present invention may advantageously sense when a hole has been completely drilled through a workpiece, and automatically retract to a starting position. In this way, drill cycle times for areas with varying material thicknesses may be optimized. Also, the need to adjust and document the stroke for power feed drilling equipment will be eliminated, as well as the need for multiple drill motor set-ups for areas with a wide range of material thicknesses.

In one embodiment, a thrust sensing valve assembly includes a housing including an input port and an output port and further having a mounting portion adapted to be coupled to a manufacturing tool. A supply member is operatively coupled to the housing to provide a flow of the pressurized medium into the input port of the housing. Finally, an elongated body is operatively coupled to the housing and moveable along an axis between a first position corresponding to a first pressure output from the housing and a second position corresponding to a second pressure output from the housing. The elongated body is biased into the first position and moveable into the second position in the presence of a thrust force on the mounting portion.

BRIEF DESCRIPTION OF THE DRAWINGS

The preferred and alternative embodiments of the present invention are described in detail below with reference to the following drawings.

FIGURE 1 is side elevational view of a drill assembly having a thrust-sensing valve in accordance with an embodiment of the present invention;

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FIGURE 2 is an enlarged side elevational view of a thrust valve assembly coupled to a drill chuck of the drill assembly of FIGURE 1 in accordance with another embodiment of the invention;

FIGURE 3 is an isometric view of the thrust valve assembly of the drill assembly of FIGURE 1 in accordance with yet another embodiment of the invention;

FIGURE 4 is an exploded side elevational view of the thrust valve assembly of FIGURE 3;

FIGURE 5 is a side elevational view of the drilling assembly of FIGURE 1 performing a drilling operation on a workpiece in accordance with an embodiment of the invention;

FIGURE 6 is a schematic view of a 4-way valve assembly of a drilling assembly in a first operating condition in accordance with yet another embodiment of the invention;

FIGURE 7 is a schematic view of the 4-way valve assembly of FIGURE 6 in a second operating condition in accordance with an embodiment of the invention;

FIGURE 8 is a schematic view of the 4-way valve assembly of FIGURE 6 in a third operating condition in accordance with an embodiment of the invention; and

FIGURE 9 is a schematic view of the 4-way valve assembly of FIGURE 6 in a fourth operating condition in accordance with an embodiment of the invention.

DETAILED DESCRIPTION OF THE INVENTION

The present invention relates to apparatus and methods for thrust-sensing valves, and more specifically, to valves that automatically retract a drilling device when thrust goes to zero. Many specific details of certain embodiments of the invention are set forth in the following description and in FIGURES 1-9 to provide a thorough understanding of such embodiments. One skilled in the art, however, will understand that the present invention may have additional embodiments, or that the present invention may be practiced without several of the details described in the following description.

FIGURE 1 is side elevational view of a drill assembly 100 having a thrust-sensing valve 110 (partially shown) in accordance with an embodiment of the present invention. In

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this embodiment, the drill assembly 100 also includes a drive motor 102 coupled to a drill chuck 104. A drill bit 106 is coupled to the drill chuck 104. As described more fully below, the drilling assembly 100 equipped with the thrust-sensing valve 100 may advantageously sense when a hole has been completely drilled through a workpiece, and will automatically retract the drill bit to its starting position.

FIGURE 2 is an enlarged side elevational view of the thrust valve assembly 110 coupled to the drill chuck 104 of FIGURE 1. FIGURE 3 is an isometric view of the thrust valve assembly 110 of FIGURE 2. The thrust valve assembly 110 includes a needle valve 111 operatively coupled to a supply gland 112, and a threaded end 114 that threadedly couples to the drill chuck 104 (FIGURE 2). The supply gland 112 is coupled to a supply line 113 that is, in turn, coupled to a source of a pressurized medium 101 (FIGURE 1), such as and air pump, a pressurized vessel, shop air, or any other suitable source.

FIGURE 4 is an exploded side elevational view of the needle valve 111 of the thrust valve assembly 110 of FIGURE 3. In this embodiment, the needle valve 111 includes an outer valve housing 116 and an inner needle body 118 that, in an assembled position, is slideably disposed within the outer valve housing 116. A spring 120 is disposed about the inner needle body 118. As further shown in FIGURE 4, a pair of pins 122 are longitudinally disposed in longitudinal keyways 123 disposed in the inner needle body 118 and corresponding longitudinal keyways 117 disposed in the outer valve housing 116. An aperture 119 is also disposed through the outer valve housing 116. A snap ring 124 secures the components of the thrust valve assembly 110 together.

Operationally, drilling torque is transmitted through the sliding, spring-loaded thrust valve assembly 110 by equipping the outer valve housing 116 and the inner needle body 118 with the longitudinal keyways 123, 117. As the outer valve housing 116 and the inner needle body 118 are assembled, the pins 122 are inserted into the keyways 123, 117. During a drilling operation, torque is transmitted from the outer valve housing 116 through the pins 122 to the inner needle body 118 without interfering with the movement necessary for the thrust valve assembly 110 to operate.

It will also be appreciated that a pressurized medium (*e.g.* air or other suitable pressurized medium) is supplied to the needle valve 111 via the supply gland 112. The

supply gland 112 is equipped with O-ring seals (not visible) that engage between an inner surface of the supply gland 112 and an outer surface of the outer valve housing 116 to minimize pressure losses. In one embodiment, snap rings may be used to maintain the position of the supply gland 112 on the outer valve housing 116. As best shown in FIGURE 3, the supply gland 112 includes an anti-rotation lug 115 that projects outwardly and fits through an opening 103 of a drill motor nosepiece 105, as shown in FIGURE 1, providing a location for coupling the supply gland 112 with the supply line 113.

FIGURE 5 is a side elevational view of the drilling assembly 100 of FIGURE 1 performing a drilling operation on a workpiece 502 in accordance with an embodiment of the invention. In this embodiment, a feedback line 513 is coupled between the needle valve assembly 111 and a control valve 510 of a drive unit 520 of the drill assembly 100.

In an upper portion of FIGURE 5, the drilling assembly 100 is shown in a first (or initial) position 504 prior to engagement with the workpiece 502. The needle valve assembly 111 is biased by the spring 120 into an open position such that a pressurized medium from the supply line 113 enters the supply gland 112, flows through the aperture 119 and through the feedback line 513 to the control valve 510. The control valve 510 is in an advance position *A* such that the drive unit 520 advances the drill bit 106 toward the workpiece 502.

As shown in a central portion of FIGURE 5, in a second (or engaged) position 506, the drill bit 106 is engaged with the workpiece 502. The needle valve assembly 111 senses the thrust of the drill assembly 100 against the workpiece 502, and the spring 120 compresses, moving the inner needle body 118 into a forward position such that the aperture 119 is blocked, thereby dropping the pressure within the feedback line 513 The control valve 510 senses the pressure drop within the feedback line 513 and remains in the advance position *A*, maintaining the drive unit 520 in the advance mode of operation and performing a drilling operation on the workpiece 502.

Finally, as shown in a lower portion of FIGURE 5, in a third (or breakthrough) position 508, the drill bit 106 has broken through the workpiece 502, removing the thrust (or compression) force on the needle valve assembly 111 and allowing the spring 120 to re-expand, withdrawing the inner needle body 118 back from the aperture 119 and returning the needle valve assembly 111 to the open position. The pressurized medium then begins to

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reflow through the aperture and re-pressurize the feedback line 513. The control valve 510 senses the return of pressure within the feedback line 513 and moves to a retract position *R*, thereby controlling the drive unit 520 of the drilling assembly 100 to withdraw the drill bit 106 from the workpiece 502. The drilling assembly 100 may then be moved to a new location over the workpiece 502, and the process repeated to form another hole in the workpiece 502.

It will be appreciated that a variety of embodiments of control valves 510 and drive units 520 may be conceived, and that the invention is not limited to the particular embodiment described above and shown in FIGURE 5. For example, in one particular embodiment, the control valve 510 may be a 4-way pneumatic valve used in conjunction with the thrust sensing valve 110 to operate an internal spool valve that controls a drill and retract cycle of a power feed drill motor, such as the type commercially available from Par-A-Matic. In this embodiment, the spool valve shifts to the feed and retract positions as air is exhausted on each side of the valve. Exhaust ports of the spool valve may be coupled to the 4-way control valve such that when the 4-way control valve is manually shifted to an advance position *A* by an operator, air (or other pressurized medium) is exhausted from a "feed" side of the spool valve and the drill motor advances. At this time, a metered air supply is being sent to the thrust sensing valve 110. The thrust sensing valve 110 air supply line 113 may also be connected to an air pilot on the 4-way valve so that when the drill starts to penetrate the material closing the thrust sensing valve 110, a back pressure is built up causing the 4-way valve t shift back to its original position *B*. In position *B*, the "retract" side of the spool valve is connected to the thrust sensing valve 110. When the drill bit (or other tool) 106 exits the back side of the workpiece, opening the thrust sensing valve 110, the air is exhausted from the "retract" side of the spool valve causing the drill motor to retract.

More specifically, FIGURE 6 is a schematic view of a 4-way valve assembly 600 of a drilling assembly 602 in a first operating condition 610 in accordance with yet another embodiment of the invention. The drill motor 604 of the drilling assembly 602 is in an initial starting position 606 with the drill bit 106 fully retracted away from the workpiece 502 (FIGURE 5). In this initial starting position 606, the drill motor 604 is in a "retract" position or mode as air exhausts out of a retract port 608. As shown in FIGURE 6, the thrust valve

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assembly 110 (FIGURES 2 and 3) is operatively coupled to the 4-way valve assembly 600 and is initially in a closed position.

Next, FIGURE 7 shows the 4-way valve assembly 600 of FIGURE 6 in a second operating condition 612 after an operator or controller (not shown) has commanded the drill motor 604 to begin drilling. The 4-way valve assembly 600 has now shifted to the second operating condition 612, with the drill motor 604 in the advance or drill position as air exhausts out of a drill port 609 of the drill motor 604. In the second operating condition 612 shown in FIGURE 7, the drill bit 106 has not yet contacted the workpiece 502 (FIGURE 5), and the thrust valve assembly 110 remains in the closed position.

FIGURE 8 shows the 4-way valve assembly 600 of FIGURE 6 in a third operating condition 614. As the drill bit 106 contacts the workpiece 502 (FIGURE 5), the thrust valve assembly 110 moves to an open position. Air pressure at a second air pilot 14 is now greater than an air pressure at a first air pilot 12, causing the 4-way valve assembly 600 to shift to the third operating condition 614. As shown in FIGURE 8, in the third operating condition 614, air exhausts our of both the drill and the retract ports 609, 608 of the drill motor 604. The drill motor 604 remains in the drill or advance position, and continues to advance the drill bit 106 into the workpiece 502 (FIGURE 5).

Finally, FIGURE 9 shows the 4-way valve assembly 600 in a fourth operating condition 616. In the fourth operating condition 616, the drill bit 106 has broken through the back side of the workpiece 502 (FIGURE 5). The thrust valve assembly 110 returns to the closed position, and air exhausts out of the retract port 608 of the drill motor 604 only. The drill motor 604 then returns to the initial retract position, automatically withdrawing the drill bit 106 back away from the workpiece 502 (FIGURE 5). The drill assembly 602 may then be re-positioned over another location of the workpiece 502, and the operation repeated.

Apparatus and methods in accordance with the present invention may provide significant advantages over the prior art. As described above, manufacturing assemblies equipped with the thrust-sensing valve may advantageously sense when a hole has been completely drilled through a workpiece, and will automatically retract to a starting position. In this way, drill cycle times for areas with varying material thicknesses may be optimized. Also, the need to adjust and document the stroke for power feed drilling equipment will be

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eliminated, as well as the need for multiple drill motor set-ups for areas with a wide range of material thicknesses.

While various preferred and alternate embodiments of the invention have been illustrated and described, as noted above, many changes can be made without departing from the spirit and scope of the invention. Accordingly, the scope of the invention is not limited by the disclosure of the preferred embodiment. Instead, the invention should be determined entirely by reference to the claims that follow.

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